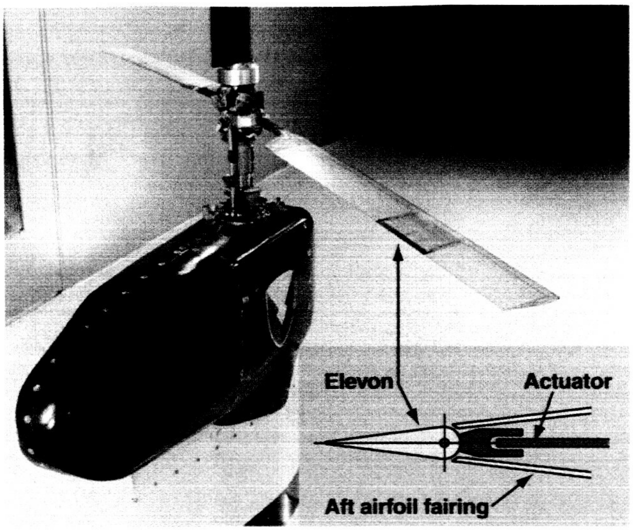

Fig. 1. Active rotor with on-blade elevons in the Ames 7- by 10-Foot Wind Tunnel.

by 13%. A tip loss for lift can be predicted by conventional lifting-line theory when nonuniform inflow exists. This approach, however, does not work for pitching moment, suggesting that the incorporation of an advanced lifting-line model may be warranted. Less significant was the inclusion of a model of elevon dynamics, which increased the torsion peak response by 6% and also caused a coupling between blade response and elevon motion. Results from forward flight tended to confirm the hover results, but suffered from the conventional problems of vibratory load prediction for helicopter rotors—the general trends were captured, but significant differences existed. For example, a correlation plot of the 2–5 per-revolution flap bending moment harmonics was produced for four wind tunnel speeds. A least-squares curve fit yielded a correlation coefficient of 0.56, indicating a low level of correlation between the analysis and the test data.

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Full-Span Tilt-Rotor Aeroacoustic Model

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Tilt rotors are a new breed of subsonic aircraft developed for both military and civil aviation. The current production of the military V-22 Osprey and the launch decision of the BA-609 civil tilt rotor will certainly enhance the U.S. military and economic competitive status in the international aviation arena. In addition, civil tilt rotors have the potential to increase air transportation throughput in congested airports by off-loading busy runways. To support the U.S. civil tilt-rotor development, NASA created the Short Haul Civil Tiltrotor project (SHCT) from the Aviation Systems Capacity program.

The SHCT program addresses critical enabling technologies for civil tilt rotors that include low-noise tilt rotors. NASA Ames and Langley Research Centers, the U.S. Army Aeroflightdynamics Directorate, and the U.S. rotorcraft industry, have jointly developed an aeroacoustic research program aimed at accomplishing the SHCT goals. One of the major milestones of the program is to validate aeroacoustic analyses for low-noise tilt-rotor designs. The primary objective of the Tilt-Rotor Aeroacoustic Model (TRAM) project is to provide a comprehensive database for code validation.

The TRAM is a quarter-scale V-22 model with two configurations: an isolated rotor configuration and a full-span, dual-rotor aircraft configuration. The TRAM isolated rotor was tested in the Duits-Nederlandse Wind Tunnel in the spring of 1998. The Full-Span TRAM (FS TRAM), shown in the figure, was installed and will be tested in the NASA Ames 40- by 80-Foot Wind Tunnel to provide aeroacoustic data for the complete aircraft configuration.

The FS TRAM is a highly complex aircraft model designed to accommodate many aspects of tilt-rotor research. The model has two rotor balances, one per rotor, and a fuselage balance. The pressure-instrumented blades provide high-frequency air-load measurements, and wing-mounted pressure tabs provide data about rotor-wing interaction effects. In addition, both wings and blades are instrumented with strain gauges for safety-of-flight monitoring and structural load measurements. The data generated from the FS TRAM wind tunnel test will be a unique

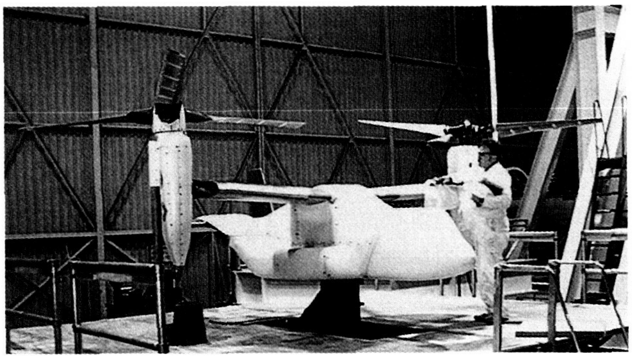

Fig. 1. Full-span TRAM under development at NASA Ames Research Center.

and valuable asset in the development of aeroacoustic analyses for advanced tilt-rotor designs.

In addition to the intensive hardware and instrumentation build-up, significant progress has been made on the FS TRAM, including the complete checkout of two new electromagnetic motors, the left rotor drive system, and the new control system. A 700-channel slip ring was completely wired, and the new rotor hubs were installed. Furthermore, modifications made to the existing microphone traverse system will allow measurements of the acoustic directivity of both rotors. Significant preparations are under way to install a particle image velocimetry system for detailed flow measurements and a laser light sheet system for flow visualization of the rotor wakes.

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Active Control of Tilt-Rotor Aeroacoustics

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Tilt-rotor aircraft have great potential to relieve air traffic congestion by ferrying passengers directly to and from vertiports located near urban areas. Since these aircraft operate like helicopters during landing, the tilt rotors produce highly impulsive noise owing to blade-vortex interactions (BVI). Thus, reducing BVI noise is a key enabling technology that will allow tilt rotors to operate in populated areas. Higher harmonic control (HHC) was shown to be highly effective in reducing BVI noise on tilt rotors. For a three-bladed rotor, an HHC system generates low-amplitude blade-pitch oscillations two, three, and four times per rotor revolution that are superimposed with the primary control input for trim. In addition, practical applications of HHC to tilt rotors require the development of suitable signal processing techniques to identify the radiated BVI noise for feedback control. A method using pressure sensors mounted on the blades for identification and control of BVI noise was demonstrated in an 80- by 120-foot wind tunnel test of a full-scale XV-15 tilt rotor. The controller successfully reduced the BVI noise level by more than 5 decibels, as indicated by the measured noise contours under the rotor shown in the figure on the following page.

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